Development of an Innovative Oxygen Scavenging Label: A journey from the Idea to the Product

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- Institute of Biotechnology
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Innovative and sustainable processes and packaging development for optimal food quality and safety
Research Fields

Innovative Packaging Materials
- Active Packaging
- Antimicrobial films
- Oxygen Scavengers
- Moisture Scavengers
- High barrier materials

Biopackaging
- Biobased materials
- Biodegradable materials
- Sustainable packaging development

Development and Optimization of Packaging Processes
- Modified atmosphere packaging
- Controlled atmosphere packaging
- Integration in food processing
- New packaging processes

Shelf life simulations
- Shelf life simulations
- Optimal packaging design
- Optimization of packaging
- Optimization of storage cond.
Content

1. Active Packaging

2. Development of Palladium based Oxygen Scavenging Label
   - Idea
   - Development
   - Industrialisation

3. Applications
1. Active Packaging

2. Development of Palladium based Oxygen Scavenging Label
   - Idea
   - Development
   - Industrialisation

3. Applications
Active Packaging

Active Packaging: “...designed to deliberately incorporate components that would release or absorb substances into or from the packaged food or the environment surrounding the food“

Regulation (EC) No 1935/2004 A

Abstract: The traditional role of food packaging is continuing to evolve in response to changing market needs. Current demands such as consumers' demand for safety, “healthiness,” and higher-quality foods, ideally with a long shelf-life; the demand for convenient and transparent packaging, and the preference for more sustainable packaging materials, have led to the development of new packaging technologies, such as active packaging (AP). As defined in the European regulation (EC) No 450/2009, AP systems are designed to “deliberately incorporate components that would release or absorb substances into or from the packaged food or the environment surrounding the food.” Active packaging materials are thereby “intended to extend the shelf-life or to maintain or improve the condition of packaged food.” Although extensive research on AP technologies is being undertaken, many of these technologies have not yet been implemented successfully in commercial food packaging systems. Broad communication of their benefits in food product applications will facilitate the successful development and market introduction. In this review, an overview of AP technologies, such as antimicrobial, antioxidant or carbon dioxide-releasing systems, and systems absorbing oxygen, moisture or ethylene, is provided, and, in particular, scientific publications illustrating the benefits of such technologies for specific food products are reviewed. Furthermore, the challenges in applying such AP technologies to food systems and the anticipated direction of future developments are discussed. This review will provide food and packaging scientists with a thorough understanding of the benefits of AP technologies when applied to specific foods and hence can assist in accelerating commercial adoption.

Keywords: active packaging, antimicrobial packaging, antioxidant releaser, ethylene absorber, oxygen scavenger

A concise guide to active agents for functional food packaging

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1. Active Packaging

2. Development of Palladium based Oxygen Scavenging Label
   - Idea
   - Development
   - Industrialisation

3. Applications
Oxidation of Food

Oxidation

Growth of aerobic microorganisms

Discoloration and rancidity

Moulds and other Spoilage organisms

Degraded appearance and nutritional value

Lost freshness, unpleasant taste and aroma

Impaired sensory qualities

Reduced Shelf life
Modified Atmosphere Packaging

- Gas Flushing
- Modified Atmosphere Packaging

Up to 3-5% residual oxygen
Oxygen Scavengers

*J. Dairy Res.* (1961), 28, 285

Gas packing milk powder with a mixture of nitrogen and hydrogen in the presence of palladium catalyst

BY J. ABBOT AND R. WAITE

*The Hannah Dairy Research Institute, Ayr*

AND

J. F. HEARNE

*Ministry of Agriculture, Fisheries & Food, London*
Palladium-based Oxygen Scavenger

\[ \text{H}_2 + \frac{1}{2} \text{O}_2 \xrightarrow{\text{Pd}} \text{H}_2\text{O} \]

Pd Deposition Thickness

Oxygen Concentration [%]

Time [h]

PET/Pd

Pd Coated Surface Analysis

- Pd coated surfaces were analyzed using **scanning electron microscopy**
- 100 nm to 20 nm surface is flat
- A sponge like structure in 10 and 5 nm sample
- 10 nm sample is more dense than 5 nm sample
Palladium-based Oxygen Scavenging Label

H₂ + ½ O₂ → H₂O

Effect of Coating Substrate on the Oxygen Scavenging Activity

Effect of Palladium Deposition Thickness on the Oxygen Scavenging Activity

Oxygen Scavenger

Palladium

SiO\textsubscript{x}

Substrate

Best Substrates:
- PET
- PET/AlO\textsubscript{x}
- PLA
- LDPE
- oPP
Effect of Coating Substrate on the Oxygen Scavenging Activity

**Oxygen Scavenger**

Best Substrates:
- PET
- PET/AlOx
- PLA
- LDPE
- oPP

**Diagram**

- PET/\(\text{SiO}_x\)/Pd
- PET/AlOx/\(\text{SiO}_x\)/Pd
- PLA/\(\text{SiO}_x\)/Pd
- LDPE/\(\text{SiO}_x\)/Pd
- oPP/\(\text{SiO}_x\)/Pd
Oxygen Scavenging Activity in the Presence of Food

Catalyst Poisoning by Volatile Sulphur compounds (VSCs)


# Volatile Sulphur Compounds (VSCs) in Foods

<table>
<thead>
<tr>
<th>Volatile sulphur compounds (VSCs)</th>
<th>Beef (Roast Beef)</th>
<th>Pork (Ham)</th>
<th>Potato Chips</th>
<th>Roasted Peanuts</th>
<th>Cheese</th>
<th>Bread</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dimethyl sulphide (DMS)</td>
<td>x</td>
<td></td>
<td>x</td>
<td>x</td>
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<td>x</td>
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<tr>
<td>Dimethyl disulphide (DMDS)</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Dimethyl trisulphide (DMTS)</td>
<td>x</td>
<td>x</td>
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<td>x</td>
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<td>x</td>
</tr>
<tr>
<td>Furfuryl thiol (FFT)</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
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</tr>
<tr>
<td>Methional (MET)</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
</tbody>
</table>
Pd Scavenging Activity in the Presence of VSC

(1) Tray
(2) Palladium-coated film
(3) Sensor spot
(4) Glass petri dish + VSC-Solution
(5) Lidding film
Pd Scavenging Activity in the Presence of VSC

VSC concentration increase by 1 order of magnitude

Determination of Minimum Inhibitory Concentrations Range of VOC

VSC Buffer Solutions

Head Space Analysis

Food Products
Minimum Inhibitory Concentration Range of VOC

<table>
<thead>
<tr>
<th>Absolute concentration / ppbv</th>
<th>Volatile Sulphur Compounds</th>
</tr>
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<tr>
<td>0</td>
<td>DMS (H₃C─S─CH₃)</td>
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<tr>
<td>2,5</td>
<td>FFT (O─CH₂─SH)</td>
</tr>
<tr>
<td>5</td>
<td>DMDS (H₃C─S─S─CH₃)</td>
</tr>
<tr>
<td>7,5</td>
<td>Methional (H₃C─S─CH₂─COH)</td>
</tr>
<tr>
<td>10</td>
<td>DMTS (H₃C─S─S─S─CH₃)</td>
</tr>
</tbody>
</table>
### Further VSC

<table>
<thead>
<tr>
<th>VSC [ppbv]</th>
<th>Roast beef</th>
<th>Ham</th>
<th>Cheese</th>
<th>Peanuts</th>
<th>Par-baked buns</th>
<th>Potato Chips</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>identified</td>
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<tr>
<td>Hydrogen sulphide</td>
<td>1.4</td>
<td>14.8</td>
<td>0.8</td>
<td>0.7</td>
<td>0.1</td>
<td>&lt;LOQ</td>
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<tr>
<td>Methane thiol</td>
<td>1.6</td>
<td>49.2</td>
<td>13.8</td>
<td>92.9</td>
<td>1.8</td>
<td>0.5</td>
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<tr>
<td>Methyl ethyl sulphide</td>
<td>5.4</td>
<td>3.5</td>
<td>1.2</td>
<td>0.4</td>
<td>0.3</td>
<td>&lt;LOQ</td>
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<tr>
<td>Thiophene</td>
<td>0.1</td>
<td>0.07</td>
<td>0.1</td>
<td>0.9</td>
<td>0.4</td>
<td>0.05</td>
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<tr>
<td>Thiazole</td>
<td>0.05</td>
<td>0.2</td>
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<td>&lt;LOQ</td>
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<tr>
<td>2-Methyl thio acetaldehyde</td>
<td>0.3</td>
<td>0.1</td>
<td></td>
<td></td>
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<tr>
<td>Butane thiol</td>
<td>3.5</td>
<td>7.7</td>
<td>5.7</td>
<td>0.3</td>
<td>4.4</td>
<td>0.1</td>
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<tr>
<td>2-Methyl thiophene</td>
<td>0.2</td>
<td>0.2</td>
<td>0.3</td>
<td>1.2</td>
<td>0.6</td>
<td>0.08</td>
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<td>4-Methyl thiazole</td>
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<tr>
<td>Methionol</td>
<td>7.8</td>
<td>0.3</td>
<td>6.0</td>
<td>4.2</td>
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<td>3-Mercapto-2-pentanone</td>
<td>0.8</td>
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<tr>
<td>Methyl propyl disulphide</td>
<td>0.1</td>
<td>0.1</td>
<td>0.4</td>
<td></td>
<td>0.2</td>
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<tr>
<td>Methyl benzene thiol</td>
<td>0.1</td>
<td>0.08</td>
<td>&lt;LOQ</td>
<td></td>
<td>2.1</td>
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<tr>
<td>2-Acetyl thiophene</td>
<td>0.4</td>
<td>0.09</td>
<td>0.07</td>
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<tr>
<td>2-Acetyl thiazole</td>
<td>0.1</td>
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<td></td>
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<tr>
<td>2,4,5-Trimethyl thiazole</td>
<td>0.1</td>
<td></td>
<td></td>
<td>&lt;LOQ</td>
<td></td>
<td></td>
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<tr>
<td>Methyl furfuryl thiol</td>
<td>0.1</td>
<td>0.07</td>
<td></td>
<td></td>
<td>0.1</td>
<td></td>
</tr>
<tr>
<td>Tetramethyl thiourea</td>
<td>0.3</td>
<td></td>
<td>0.4</td>
<td></td>
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<td>0.6</td>
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<tr>
<td>Benzo thiazole</td>
<td>0.1</td>
<td>0.1</td>
<td>&lt;LOQ</td>
<td></td>
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<td>0.1</td>
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<tr>
<td>Ethyl 3-(methyl thio) propanoate</td>
<td>0.4</td>
<td></td>
<td>0.2</td>
<td>&lt;LOQ</td>
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<tr>
<td>2-Methyl benzo thiazole</td>
<td>0.1</td>
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<td>&lt;LOQ</td>
<td>&lt;LOQ</td>
<td></td>
<td></td>
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<tr>
<td>Propyl disulphide</td>
<td>0.3</td>
<td>0.1</td>
<td>&lt;LOQ</td>
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<tr>
<td>Bis-(2-methyl-3-furyl) disulphide</td>
<td>&lt;LOQ</td>
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</tr>
</tbody>
</table>
Label Development

1. Step: SiOx/Pd-Coating

2. Step: Partial application of Adhesive

3. Step: Application of FCM

4. Step: Punching
Content

1. Research Group Food Packaging @ZHAW

2. Active Packaging

3. Development of Palladium based Oxygen Scavenging Label
   - Idea
   - Development
   - Industrialisation

4. Applications
Use of palladium based oxygen scavenger to prevent discoloration of ham

Hutter S., Rüegg N., Yildirim S., Use of palladium based oxygen scavenger to prevent discoloration of ham, Food Packaging and Shelf Life, 2016, 8, 56-62
Use of Palladium based Oxygen Scavenger to Prevent Oxidation in Linseed Oil

Faas N., Röcker B., Smrke S., Yeretzian C., Yildirim S. Prevention of lipid oxidation in linseed oil using a palladium-based oxygen scavenging film, Food Packaging and Shelf Life, to be submitted
Use of Palladium based Oxygen Scavenger to Prevent Mould Growth of Bakery Products

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